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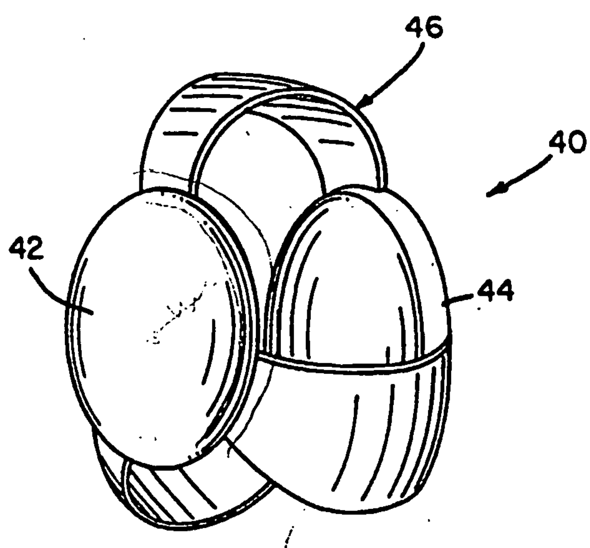
(54) Title: OPEN CHAMBER, ELLIPTICAL, ACCOMMODATIVE INTRAOCULAR LENS SYSTEM

(57) Abstract

An open chamber, accommodative, intraocular lens method, and apparatus operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens, is provided having an anterior refractive lens optic (42); a first haptic segment (46) having a first end, being connected at the first end to peripheral portion of the anterior lens optic, and a second end; and the haptic segment extending in an elliptical curve, in longitudinal cross section; and at least a second haptic segment (46) having a first end, being connected at the first end to a peripheral portion of the lens optic, and a second end; and at least a second haptic segment extending in an elliptical curve, in longitudinal cross section, and being operably joined with the second end of the first haptic segment to form an open chamber, elliptical shaped haptic accommodating support for the anterior lens within an evacuated capsular bag of a human eye.



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OPEN CHAMBER, ELLIPTICAL, ACCOMMODATIVE INTRAOCULAR LENS SYSTEM

Related Patent

This application is related in part to my prior United States patent No. 5,275,623 entitled "Elliptical Accommodative Intraocular Lens for Small Incision Surgery" dated January 4, 1994.

BACKGROUND OF THE INVENTION

This invention relates to an improved elliptical, accommodative, intraocular lens system operable to be positioned within the interior of an evacuated capsular bag of a human eye. More specifically, this invention relates to an open elliptical, accommodative, intraocular lens method and apparatus operable to be inserted within an evacuated capsular bag of a human eye following extracapsular surgery to remove and replace a dysfunctional natural crystalline lens. The invention finds particular application in restoring bifocal vision following cataract surgery, correction of myopia, correction of presbyopia and treatment of the symptoms of retinal damage, such as, age related macular degeneration of the human eye.

In the human eye, bifocal vision is provided by a combination of a convex-concave lens, known as the cornea, positioned in front of the iris and a bi-convex lens position within a clear elliptical envelope behind the iris and in front of the vitreous humor of the eye. Accommodation of vision at both infinity and near

vision of 250 mm is provided by a peripheral muscular body extending about the capsular bag and connected to the equator thereof by Zonula of Zinn which are thin strands attaching the equator of the capsular bag to the ciliary muscles. Tension and the relaxation of the ciliary muscles causes the capsular bag to lengthen or contract which varies the focus of the eye.

In certain instances at an early age, such as trauma or heredity, or in later stages of the life cycle, the natural crystalline lens of a human becomes cloudy and hardened, somewhat like milk glass, which occludes vision and results in eventual blindness. This condition is known as a cataract and was a major source of blindness in mankind for centuries. As early as 1766 Cassanova, in his memoirs, suggested that an intraocular lens could be implanted within a human to replace an opaque natural crystalline lens. It was not until 1949, however, that a Dr. Harold Ridley, at the Thomas Hospital in London, inserted the first intraocular lens within the eye of a woman of about 60 years of age following cataract extraction. Early IOLs, however, tended to dislocate, cause iris atrophy and in some instances secondary glaucoma. Attempts to overcome the early disadvantages of Dr. Ridley's solid posterior chamber lens included placement of a lens in the anterior chamber, in front of the iris. In addition Dr. Binkhorst of Holland invented an iris clip lens and Dr. Choyce an iris plane lens. However, both anterior chamber and iris fixed lenses created a risk of damages to delicate iris tissue.

An advanced in the intraocular lens art occurred when Dr. Shearing invented the first, practical, posterior chamber lens. Dr. Shearing's design

included a bi-convex polymethylmethacrylate (PMMA) lens body which was positioned behind the iris and against the ciliary muscle or within the capsular bag. The Shearing IOL was maintained in a generally central axis of vision by thin strand haptics that extended radially from the peripheral edge of the lens optic and were curved at their distal ends. The curved portions of the haptics abutted against peripheral tissue of the eye to support the lens. Although the Shearing lens haptics had small arc contact zones, the success of the lens lead other pioneers to develop a variety of haptic designs, such as, a C-loop or an S-loop and other designs to relieve trauma to adjacent contact tissue. A significant limitation of all fixed focus intraocular lens designs is that the focal point is fixed at infinity. Accordingly, for all near vision tasks, conventional reading glasses became necessary. In this connection, it is believed the several million pair of reading glasses are sold annually within the United States alone.

In addition to the incidences of cataract formation and its attendant tendency to blindness, reductions in both amplitude and speed of accommodation with age are well known. This condition is known as presbyopia. The amplitude of accommodation decreases progressively with age from some 14 diopters in a child of ten years to near zero at age 52. The exact explanation for the physiological phenomena is not well documented, however, it is observed that the curvatures of excised senile lenses were considerably less than those of juvenile ones. This failure could be due to a hardening of the lens material, sclerosis, decrease in modules of elasticity, or to a decrease in thickness of the capsule or a

combination of the above. Regardless f the cause, it is a rec gnized fact that beginning at about age 40 – 45 correction for both near and far vision becomes necessary in most humans. Conventional techniques include bifocal glasses, bifocal contact lens, contact lenses for distance and reading glasses for near vision, and mono-focus contact lens sets where one eye carries a contact lens for distance vision and the other eye carries a contact lens for reading. Still further refractive surgery for distance vision coupled with reading glasses has been used successfully to correct presbyopia. Notwithstanding the grateful relief of being able to see clearly at both near and distance, all of the above solutions are compromises, in one form or another, and are dramatically more inconvenient than the natural bifocal vision of youth.

A somewhat related visual dysfunction in youth and young adults is mild to severe myopia or the loss of an ability to clearly focus at distance. Glasses, contact lenses or refractive surgery are the most common forms of accommodation, however, with certain cases of myopia it may be necessary to correct vision up to 30 to 40 diopters. As the degree of myopia increases the use of conventional solutions becomes less attractive and it would be highly desirable to be able to reliably correct this patient concern.

Still further, as humans age, or through viral inflammations or trauma, deterioration in retinal cells, including macular degeneration, can cause a dramatic loss of perception of light and color by rods and cones of the retina. In certain instances a degree of relief for humans suffering from impairment of vision from

the loss of retinal cells can be achieved by increasing the intensity r magnification of images presented to healthy cells. In certain instances of macular degeneration it would be desirable to present a patient with an option f a correction f 30 to 70 diopters. This magnitude of correction is not readily achievable with presently known techniques.

The limitations to vision outlined in the proceeding are not intended to be exhaustive but are major concerns and represent limitations placed on mankind of impaired vision occasioned from trauma, disease, and/or age. It would be highly desirable if these limitations could be addressed and minimized or eliminated and thus restore to patients at least a portion of the accommodation and clarity of the vision of their youth.

OBJECTS OF THE INVENTION

It is a general object of the invention to provide a method and apparatus to obviate or minimize limitations to accommodated bifocal vision of the type previously described.

It is another object of the invention to provide an intraocular lens system which to operable to restore a patient's bifocal vision following extracapsular cataract extraction.

It is a further bject of the invention to provide an intraocular lens system which can be used as a replacement of a patient's natural crystalline lens to accommodate and offset presby pia limited vision with age.

It is a related object of the invention to provide an intraocular lens system that can be used in place of a patient's natural crystalline lens to correct instances of mild to severe myopia.

It is yet another object of the invention to provide an intraocular lens system which can be used to improve vision in patients having retinal deterioration, such as, macular degeneration.

It is a specific object of the invention to provide an intraocular lens system that is operable to utilize the natural physiology of the human eye to restore accommodative bifocal vision to a patient.

It is yet another object of the invention to restore a patient's bifocal vision following cataract surgery or for correction of presbyopia without using refractive surgery, contact lenses, or glasses as a part of the corrective solution.

It is still another object of the invention to provide an intraocular lens system solution to creation of a vision augmentation of 70 to 90 diopters without use of thick glasses or radical refractive surgery

SUMMARY OF THE INVENTION

In at least one preferred embodiment of the invention intended to accomplish the above, and other, objects of the invention are achieved by an pen chamber, acc mm dative, intraocular lens system operable to be positioned within the interior of an evacuated capsular bag of a human eye. The inventive intraocular lens system includes a first anterior lens optic and a second posterior lens optic which are arranged in axial alignment visually. An open chamber, haptic system is connected between the two lenses and in a preferred form three haptics segments are fashioned in the form of elliptical segments which are connected at their ends to the peripheral rims of the lens bodies and arc outwardly away from the visual axis of the lenses.

The overall cross-sectional shape of the inventive intraocular lens system is elliptical and is designed to fit smoothly within the interior of a patient's capsular bag. The elliptical haptic elements are flexible and as the capsular bag is peripherally pulled outwardly at its equator the bag contracts. This contraction is produced by a patient's natural vision accommodative by the ciliary muscles of the eye. In this, the anterior lens is moved axially toward the posterior lens to provide vision at infinity. As the ciliary muscles are constricted and move radially inward, for near vision accommodation, tension on connective zonuals decreases and the patient's capsular bag thickens allowing the haptics to assume their natural memory state.

Although the use of a two optic lens system is preferred, wherein the anterior lens is bi-convex and the posterior lens is concavo-convex to a provide

corrective range of acc mmodation f about 4 diopters following extracapsular cataract surgery, other lens embodiments are c ntemplated by the subject invention. In this, ther lens cross-sectional configurations can be used ,such as for example, concavo-planar or concavo-convex for either the anterior of posterior lens. In still other instances it may be desirable to remove the posterior lens entirely or eliminate its optic function by using a biplanar lens body. Finally, the invention also envisions adding more than two lenses, such as three lenses, in instances where extreme dioptive correction is desirable.

In a preferred embodiment three elliptical haptic segments are use extending at an arc of about 40 degrees outwardly from the rims of the lens optics and are peripherally spaced around the periphery with 80 degree segments of open space. These haptic segments are elliptical in cross-section and are fashioned in a natural state to have an elliptical ratio of 0.96. Other arrangements of the haptics are also envisioned such as two wider based haptics or four or more haptics that would be thinner in outer width. The underlying criteria is that the haptics are flexible enough to enable relatively unrestricted accommodation movement of the anterior lens toward the posterior chamber lens of about 1.9 mm or so in response to the natural movement of the ciliary muscle and zonula attached to the capsular bag while simultaneously being stiff enough to support the lens or lenses of the optic system in visual axial alignment within the capsular bag of a patient's eye.

BRIEF DESCRIPTION OF THE DRAWINGS

Other bject and advantages f the present invention will become apparent from the following detailed description of preferred embodiments of the invention taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a partial cross-sectional view of a human eye including a lens system composed of a convex-concave cornea and an accommodative, bi-convex natural crystalline lens positioned within a posterior chamber capsular bag;

FIGURE 2 is a partial cross-sectional view of a human eye as depicted in FIGURE 1 where the natural crystalline lens has been replaced with an open chamber, accommodative, intraocular lens in accordance with one preferred embodiment of the invention to restore a patient's natural, accommodative, bifocal vision following extracapsular surgery;

FIGURE 3 (note sheet two) is and axonometric view of an open chamber, accommodative, intraocular lens having three elliptically shaped haptics extending between an anterior lens optic and a posterior lens optic in accordance with one preferred embodiment of the invention;

FIGURE 4 is an end view of the open chamber intraocular lens system, as depicted in FIGURE 3, and viewed along a visual axis as the lens is implanted within the capsular bag of a human eye;

FIGURE 5 is a side view of the intraocular lens system including a preferred form of three equally spaced haptic segments, as depicted in FIGURE 4;

FIGURE 6 (note sheet 3) is a plan view of a haptic component disclosing its preferred, general elliptical, configuration;

FIGURE 7 is a cross-sectional view of the haptic component depicted in FIGURE 6 and discloses the arcuate cross-sectional configuration of the haptic element;

FIGURE 8 is a schematic and axonometric illustration of an open chamber, elliptical, accommodative intraocular lens segment in accordance with a preferred embodiment of the invention positioned within the capsular bag of a human eye;

FIGURE 9 is a partial schematic side view of the accommodative, intraocular lens system, depicted in FIGURE 8, in accordance with the invention which discloses the longitudinal elliptical configuration of a haptic of the lens system;

FIGURE 10 is a schematic illustration of the motion of the open chamber, elliptical, accommodative, intraocular lens system in accordance with a preferred embodiment of the invention, depicted in FIGURES 8 and 9, wherein phantom lines represent a segment of the lens in a natural memory condition following insertion into the capsular bag of a patient's eye, with the patient's ciliary muscle constricted inward to accommodate for near vision, and the solid line segment depicts the position of the lens system when the patient's ciliary muscle relaxes and peripherally expands and stretches the capsular bag outward narrowing the distance between the lens optics to provide accommodative vision at infinity;

FIGURE 11 (note sheet four) is an illustration f another preferred form of the invention where the open chamber, elliptical, accommodative intraocular lens system includes only ne anterior positioned lens optic;

FIGURE 12 is an illustration of another preferred form of the invention having only one anterior positioned lens optic;

FIGURE 13 is an axonometric illustration of another preferred embodiment of the invention where the intraocular lens system includes three lens optics in axial alignment; and

FIGURE 14 is a cross-sectional view of a three lens optic system as illustrated in FIGURE 13.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Turning now to the drawings wherein like numerals indicate like parts, there will be seen preferred embodiments of the invention. Before describing the preferred embodiment, however, a brief statement about the context of the invention is believed appropriate.

Context of the Invention

Turning now to Figure 1 there will be seen a partial cross-sectional view of an anterior segment of a human eye 20. Vision in humans is provided by a first convex/concave lens known as a cornea 22. This segment is partially spherical and

is transparent to light. The c rnea 22 is connected at its perimeter to a generally spherical exterior b dy f the eye known as a sclera 24. An iris 26 is positioned within an anterior chamber of the eye 28 and serves to vary the amount of light permitted to pass into the eye structure. The iris 26 extends into and is joined with a muscular structure known as the ciliary body or muscle 30 which extends peripherally about an interior portion of the eye. A natural crystalline lens 32 is positioned behind the iris 26 and is enrobed by a capsular membrane or bag 34. The natural crystalline lens 32 approximates an ellipse in cross-section and is circular when viewed along a line of sight. Zonula of Zinn 36 extend between the ciliary muscle 30 and an equator position of the capsular bag 34. A hyloid face, not shown, extends across the posterior surface of the lens 32 and isolates the forward segment of the eye from a vitreous chamber filled with clear vitreous humor.

Light is focused by the human eye by being refracted through the cornea and then refracted again through the bi-convex natural crystalline lens and is focused on a retina at the base of the eye. Bifocal vision from infinity to 250 millimeters is accommodated by varying the shape of the natural crystalline lens 32. More specifically, images at infinity are focused by the ciliary muscle 30 relaxing which permits their peripheral expansion and thus tensioning the zonula 36. Tension of the zonula draws the equator of the capsular bag radially outward and foreshortens the thickness of the lens body 32, providing for distance vision. In contrast, near vision is accommodated in a human eye by the ciliary muscles

contracting which releases tension on the zonula allowing the lens body 32 to thicken into its natural state and thus focusing near objects upon the retina f r transmission to the brain by the optic nerve.

A human eye adapts readily to variations in focal length and seamlessly enables a human to view objects at infinity as well as near vision instantly without conscious accommodation. Notwithstanding the perfect vision enjoyed by a majority of the population, an inability to view objects at infinity, or myopia, is frequently encountered. This visual impairment can be corrected by refractive lens held by glasses, wearing contact lens or refractive surgery. In addition, certain humans do not focus near vision well. This is known as hyperopia and their vision can also be corrected by conventional refractive techniques. In certain instance of severe lack of accommodation these conventional procedures become undesirable and alternative procedures are needed.

Although a youth of ten years in age has an ability to change the dioptic power by fourteen diopters, this ability gradually decreases with age and by fifty or so the ability of the human eye to accommodate variation in focal length becomes essentially zero. This condition is referred to by presbyopia and a patient often requires correction for both near vision and far vision. This can be achieved by wearing bifocal glasses or contacts or undergoing refractive surgery for distance and wearing glasses for reading purposes.

In addition to the foregoing more conventional limitations on 20/20 vision, in instances of juvenile disease, trauma, and more frequently through age, the

natural crystalline lens 32 becomes rigid and opaque to the passage of light. This condition is referred to as a cataract which can be corrected by removal of the lens 32 by a number of techniques, however, the most commonly perform surgery is known as extracapsular extraction. In this procedure, an annular opening is fashioned about the anterior visual center of the lens, centered by the iris, and then emulsifying and aspirating the hardened lens material. At least one procedure for phacoemulsification, irrigation and aspiration is disclosed in a United States Shearing Patent No. 5,154,696. Once the natural crystalline lens is removed a bi-convex, fixed focal length optic, of about six millimeters in diameter, is typically fitted into the capsular bag and held in position by radially extending haptics. Although cataract surgery and insertion of an intraocular lens is the most frequently performed surgical procedure in the United States, and has achieved a considerable degree of sophistication and success, an intraocular lens is selected with a diopter to achieve far vision and near vision must be corrected by wearing reading glasses.

Finally, retinal disease or damage can impair human vision and one form is known as macular degeneration which usually occurs with advance in age. The symptom of macular degeneration can be alleviated, to a degree, by providing high diopters in the 30 to 70 range such that the rods and cones available to receive sight are utilize to their fullest.

From the foregoing context it will be appreciated that improvements in the eye care industry can be made with respect to correction of vision such as myopia,

hyperopia, presby pia, replacement of bifocal vision following cataract extraction and treatment of retinal dysfunction such as macular degeneration.

Open Chamber, Elliptical, Accommodated, Intraocular Lens System

Referring now to Figure 2, the subject invention is directed to an open chamber, elliptical, accommodated, intraocular lens system 40 which is operable to correct and/or eliminate vision impairments of the type described above. The intraocular lens system 40 includes an anterior lens 42, a posterior lens 44 and haptic segments 46 operably connecting the anterior lens 42 with the posterior lens 44. As noted in Figure 2, the subject intraocular lens system 40 is substantially elliptical in cross-section and operably conforms to the interior three-dimensional surface of the capsular bag 34.

Turning to Figures 3 - 5 of the drawings, at sheet two, there is shown an axonometric view of the subject intraocular lens system 40, a front view, and a side view, respectively. The forward or anterior optic 42 is preferably bi-convex as depicted in Figure 5 and has a diameter of approximately five millimeters for positioning within the capsular bag 34 immediately behind the iris 26. The power distribution of the anterior and posterior lenses may be varied to suit the needs of the particular patient, however, in a preferred embodiment the anterior lens is positive and the posterior lens is negative. The posterior lens 44 is in visually, axial alignment with the lens 42 and cooperates with the anterior lens to correct a

wearer's vision. In a preferred emb diment, the lens 44 is fashioned in a spherical concavo-convex shape as depicted in Figures 3 and 5. Although in a preferred embodiment the anterior and posterior lens combinations are as stated above, other lens couples are contemplated by the subject invention including anterior lens fashioned with a concavo-planar, concavo-convex, and convex-concavo configurations. In a similar manner, the posterior lens may also exhibit the range of physical lens formation possibilities of being concave or convex or planar in order to achieve the desired visual result for a particular patient. Lenses are typically fabricated from an optical grade polymethylmethacrylate (PMMA) however other materials may be utilized such as glass, silicone, or acrylics provided visual clarity, refractive ability, and bio-compatibility are all maintained.

In the subject invention, the anterior 42 and posterior 44 lenses are coupled together by a plurality of longitudinally elliptical haptics 46. The haptics are connected to the peripheral edges of the anterior and posterior lenses by stalking, integral formation, gluing, or other known techniques and are positioned on the peripheral edges of the lenses in equidistant peripheral locations. In a preferred embodiment, the haptics subtend an angle of thirty to forty degrees as viewed in a direction of line of sight, note Figure 4, and extend outwardly approximately nine millimeters, in diameter, to approximate the normal internal diameter of the capsular bag of the human eye. As shown in Figure 6, note sheet three, the haptic 46 is generally elliptical in a plan view and has arcuate end surfaces 48 and 50 for attachment to the periphery of the anterior and posterior lenses as noted

above. In cross-section, the haptics 46 are arcuate, note Figures 4 and 7, and have a radius of curvature f approximately 4.5 millimeters which enables the haptic to smoothly conf rm t the interior surface of an evacuated capsular bag.

The haptics 46 are preferably composed of polymethylmethacrylate (PMMA) material which can be molded along with one of the anterior or posterior lenses. In certain instances, it may be desirable to lessen the overall weight of the intraocular lens system within the interior of a patient's eye. In this instance the haptic 46 can be advantageously composed of a polypropylene material having a specific gravity of approximately 0.91 and thus the combination of the PMMA optics and polypropylene haptics offset and the lens system is approximately neutrally buoyant with the aqueous humor. In addition, the haptics can be advantageously composed of an acrylic having a water content of 2 to 30 %, a hydroxyethylmethacrylate (HEMA), or polydimethyl siloxanes.

Although three radially extending haptics covering arcs of 30 - 40 degrees each, such as shown in Figures 3 - 5, constitute a preferred embodiment of the invention, other haptic arrangements of from two to five or more in number are envisioned and can be selected by those of ordinary skill in the art to satisfy the requirement of sufficient flexibility to provide the accommodated focusing of the lens system and simultaneous stiffness to maintain the axial position and orientation of the lens optics.

Turning to Figures 8 - 10, there will be seen schematic illustrations of a portion of the subject intraocular lens system positioned within a capsular bag 34

and particularly illustrated in Figure 9 an elliptical cross-sectional configuration of the haptic 46 wherein the ratio provided by the height A of the ellipse over the length B is 0.96. It has been determined that this ratio is optimum for application of the ciliary muscles and zonula acting through the capsular bag to provide accommodative vision with the intraocular lens system 40. Although this configuration is preferred, it is envisioned that a more linear arrangement in the form of a triangle with rounded corners may be utilized to advantage provided the material, thickness and configuration remain both flexible and supportive.

Referring again to Figure 8, a peripheral zone of zonula 36 is depicted which extends peripherally about and is connected to the capsular bag 34. In a condition when the ciliary muscle 30 is relaxed and retracted peripherally outwardly, the zonula 36 will be tensioned outwardly which will pull the equator of the capsular bag 34 into a configuration shown in solid lines in Figure 10. This position of the capsular bag and the location of the anterior and posterior lenses is optimum for vision at infinity.

When the peripheral ciliary muscles 30 are constricted the hoop dimension is radially decreased which releases tension on the zonnuals 36 and the capsular bag, biased by the natural shape of the intraocular lens system 40, assumes the condition indicated by phantom lines in Figure 10. In this, the natural memory shape of the elliptical haptics 46 repositions the anterior lens 42 with respect to the posterior lens 44 axially and is the position used for focusing on near objects down to 250 millimeters. In a preferred embodiment, the subject intraocular lens system

cooperates with the ciliary muscle, and zonula and capsular bag to permit a relative axial motion of the anterior lens with respect to the posterior lens f 1.9 millimeters and a power correction of 4 diopters. This accommodated motion of the subject intraocular lens system is achieved automatically, and seamlessly, within the human eye and thus is operable to permanently restore unaided binocular vision.

Although a preferred embodiment of the subject accommodative intraocular lens system has been disclosed and discussed in connection with Figures 3 - 8, other preferred embodiments exist with respect to specific applications such as disclosed in Figures 11 - 14. In this, Figures 11 and 12 disclose elliptical haptic, intraocular lens systems utilizing a single anterior lens body 52 which may be used to advantage for the correction of mild to severe myopia (nearsightedness) or hyperopia (farsightedness). In this embodiment, a plurality of elliptical haptics 54 connect at a first end to a peripheral portion of the first optic 52 and at a second end to a stabilizing ring 56 positioned in a location posterior to and in axial alignment to the optic 52. This embodiment is operably received within an evacuated capsular bag in a secure and stable manner similar to that shown in Figure 2.

In an alternative embodiment of the invention a single lens optic 58, as depicted in Figure 12, is supported by elliptical haptics 60 having a first end connected to a peripheral rim of the optic and extend to free end positions to a location of posterior proximity. This lens will also snuggly and accommodatively

fit within an evacuated capsular bag for use in correction f myopia and hyperopia.

The cross-sectional configuration of the corrective lens 52 and 58, of the embodiments depicted in Figures 11 and 12, may be selected for the designated refractive purposes but it is preferred that the lens exhibit a concave-convex, plano-convex, or convex-plano surface configurations as viewed in cross-section.

In certain instances such as macular degeneration it may be desirable to provide an accommodative intraocular lens system wherein the lens is capable of providing hyper-visual corrections of 30 - 70 diopters. Turning to Figures 13 and 14, there is shown an accommodative intraocular lens system including an anterior lens 62, a posterior lens 64, and an intermediate lens 66. An elliptical haptic system 68 surrounds and supports the anterior and posterior lenses of the lens system in a manner as previously described. The intermediate lens 66 is supported by radially extending arms 70 which project between the peripheral surface of the interior lens and the intermediate surface of the elliptical haptic 68. This support is illustrated particularly in Figure 14 which discloses a schematic cross-sectional view taken along section lines taken through the center of adjacent haptics 68 in Figure 13. The shape and dioptive power of each of the lens 62, 64, and 66 can be varied to suit a particular patient's circumstances. In this embodiment, the anterior lens is the principal moving lens during accommodation, the intermediate lens remains essentially axially stationary, as the support members 70 elongate, with movement of the zonula, and the posterior lens may move a small degree but

less than the anterior lens 62. The power distribution f each of the lens may be varied to suit the needs f a specific patient, however, if a total power f 28 diopters is required an envisioned distributions would be eight dipoters for the anterior lens, ten diopters for the intermediate lens, and four dipoters for the posterior lens. Alternatively, the anterior lens may be four dipoters, the intermediate lens may be four dipoters, and the posterior lens twenty dipoters.

SUMMARY OF MAJOR ADVANTAGES OF THE INVENTION

After reading and understanding the foregoing description of the invention, in conjunction with the drawings, it will be appreciated that several advantages of the subject improved open chamber, elliptical, accommodative, intraocular lens system are achieved.

Without attempting to set forth all of the desirable features of the subject invention an accommodative intraocular lens system including an anterior lens and posterior lens coupled with longitudinally, elliptical haptics operably serve to replace a natural crystalline lens within a patient's evacuated capsular bag and provide an accommodation of four or more diopters suitable to restore bifocal vision to most patient's following cataract surgery.

A single, anterior lens embodiment of the invention is advantageously operable to correct both myopia and hyperopia and single or dual lens designs find use in providing full accommodative restoration of vision to presbyopic patients.

In instances of retinal damage or degeneration, where high diopter powers enhance vision, a three lens embodiment of the invention can be used to produce magnification up to seventy diopters or more.

The elliptical ratio of 0.96 provides a particularly advantageous degree of rigidity and flexibility such that a patient's ciliary muscles, zonula, and natural capsular bag are able to restore a patient's accommodative vision without using other vision correcting devices.

In describing the invention, reference has been made to preferred embodiments and illustrative advantages, those skilled in the art, however, and familiar with the instant disclosure of the subject invention, may recognize additions, deletions, modifications, substitutions and/or other changes which will fall within the purview of the subject invention and claims.

WHAT I CLAIM IS:

1. An pen chamber, accommodative, intraocular lens system operable to be positioned within the interior of an evacuated capsular bag of a human eye, said introcular lens system comprising:

a first lens optic;

a second lens optic;

a first, longitionally arcuate, haptic segment having a first end and a second end, said first haptic segment extending between said lens optics and connected at said first end to said first lens optic and connected at said second end to said second lens optic respectively; and

at least a second, longitionally arcuate, haptic segment having a first end and a second end and extending between said lens optics and connected at said first end to said first lens optic and at said second end to said second lens optic respectively, said first and second lenses being supported in general visual axial alignment, within an evacuated capsular bag by said first longitudinally arcuate haptic

and said at least a sec nd longitudinally arcuate haptic abutting against and being supported by the interior surfaces of the evacuated capsular bag and the ciliary muscles f a wearer of the intraocular lens system acting through zonuals connected to an exterior surface of the evacuated capsular bag being operable to expand and contract the capsular bag and thus the arcuate haptics to selectively vary the axial distance between said first lens and said second lens and thus facilitate near and far accommodated vision of a weraer of the intraocular lens system.

2. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein said at least a second, arcuate, lens haptic comprises:

a second and a third, longitudinally arcuate, haptic segments and said first, second and third haptic segments being peripherally space equally about the rim of said first and second lens optics.

3. An open chamber, accomodative, intraocular lens system as defined in claim 2 wherein:

said first, second and third, longitudinally arcuate, haptic segments, when viewed at an angle normal to an anterior face of said first lens ptic, extend utwardly from the periphery of the first lens optic at an angle of approximately 30 to 40 degrees and said haptics are equally spaced about the periphery of the optic.

4. An open chamber, accomodative, intraocular lens system as defined in claim 3 wherein:

said first, second and third, longitudinally arcuate, haptic segments, when viewed in longitudinaly cross-section are elliptical with a ratio of ellipse of approximately 0.96.

5. An open chamber, accomodative, intraocular lens system as defined in claim 3 wherein:

the transverse cross-sectional configuration of each of said first, second and third haptic segments is substantially a circular arc and having a radius of curvature of approximately 4.5 mm.

6. An pen chamber, accomodative, intraocular lens system as defined in claim 1 wherein said at least a second, arcuate, lens haptic comprises:

a second, third and fourth, longitudinally arcuate, haptic segments; and

said first, second, third and fourth haptic segments being peripherally spaced about the peripheral rims of said first and second lens optics.

7. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein said at least a second, arcuate, lens haptic comprises:

a second, third, fourth and fifth, longitudinally arcuate, haptic segments; and

said first, second, third, fourth and fifth haptic segments being peripherally spaced about the peripheral rims of said first and second lens optics.

8. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein said at least a second, arcuate lens haptic comprises:

two, or more, longitudinally arcuate, haptic segments each having a first end and a second end, each of said longitudianlly arcuate haptic segments extending between and connected at said first ends to spaced peripheral portions of said first lens optic and connected at said second ends to peripheral portions of said second optic.

9. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein:

said first, longitudinally arcuate, haptic segment and said at least a second, longitudinally arcuate, haptic segment are also transversly arcuate so as to fit smoothly within the interior of and abut against the interior surfaces of the evacuated capsular bag of a wearer of the intraocular lens system.

10. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein:

said first, longitudinally arcuate, haptic segment and said at least a second, longitudinally arcuate, haptic segment are generally elliptical in a planar perspective prior to attachement to the periphery positions of the first and second lens optics.

11. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein:

said first, longitudinally arcuate, haptic segment and said at least a second, longitudinally arcuate, haptic segment are gernerally rectangular in a planar perspective prior to attachment to the periphery positions of the first and second lens optics.

12. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein:

said first and second lens optics and said first and at least a second lens haptics are all composed of polymethylmethacrylate material.

13. An pen chamber, accomodative, intraocular lens system as defined in claim 1 wherein:

said first and second lens optics are composed of polymethylmethacrylate material; and

said first and said at least a second lens haptics are all composed of polypropylene having a specific gravity of less than 1.0 and thus providing offset buoyancy for the lens optics when the intraocular lens is positioned within the aqueous humor of a human eye.

14. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein:

said first and second lens optics are each composed of polymethylmethacrylate material; and

said first and at least a second haptics are composed of an acrylic material having a water content of between 2% and 30%.

15. An pen chamber, accomodative, intraocular lens system as defined in claim 1 wherein:

said first and second lens optics are each composed of polymethylmethacrylate material; and

said first and at least a second haptics are composed of hydroxyethylmethacrylate.

16. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein:

said first and second lens optics are each composed of polymethylmethacrylate material; and

said first and at least a second haptics are composed of polydimethyl siloxanes.

17. An open chamber, accomodative, intraocular lens system as defined in claim 1 wherein:

said first and second lens optics are each composed of polymethylmethacrylate material; and

said first and at least a second haptics are composed of an acrylic material having a specific gravity less than one so as to provide offsetting positive bouyancy with respect to the negative bouyancy of the lens optics.

18. An open chamber, accommodative, intraocular lens system operable to be positioned within the interior of an evacuated capsular bag of a human eye, as defined in claim 1 wherein:

said first lens optic comprises a bi-convex lens having a convex, spheric, anterior surface and a convex, spheric, posterior surface, as viewed from the perspective of the lens being placed within an evacuated capsular bag of a wearer's eye; and

said second lens optic comprises a concave-convex lens having a concave spheric, anterior surface and a convex, spheric posterior

surface, as viewed from the perspective of the lens being placed within the evacuated capsular bag if a wearer's eye.

19. An open chamber, accommodative, intraocular lens system operable to be positioned within the interior of an evacuated capsular bag of a human eye, as defined in claim 1 wherein:

said first lens optic comprises a bi-convex lens having a convex, spheric, anterior surface and a convex, spheric, posterior surface, as viewed from the perspective of the lens being placed within an evacuated capsular bag of a wearer's eye; and

said second lens optic comprises a convex-planar lens having a concave, spheric, anterior surface and a planar posterior surface, as viewed from the perspective of the lens being placed within an evacuated capsular bag of a wearer's eye.

20. An open chamber, accommodative, intraocular lens system operable to be positioned within the interior of an evacuated capsular bag of a human eye, as defined in claim 1 wherein:

said first lens optic comprises a bi-convex lens having a convex, spheric, anterior surface and a convex, spheric, posterior surface, as viewed from the perspective of the lens being placed within an evacuated capsular bag of a wearer's eye; and

said second lens optic having biplanar anterior and posterior surfaces and thus providing no refraction of light passing through the second lens from curvature of the lens surfaces.

21. An open chamber, accommodative, intraocular lens system operable to be positioned within the interior of an evacuated capsular bag of a human eye, as defined in claim 1 wherein:

axial spacing of the first lens optic with respect to the second lens optic, when positioned within an evacuated capsular bag of a human eye, is such that the ciliary muscle of the wearer is operable to effect an accommodative axial, line of sight, displacement of the first optic lens with respect to the second optic of approximately 2mm.

22. An open chamber, accommodative, intraocular lens system operable to be positioned within the interior of an evacuated capsular bag of a human eye, as defined in claim 1 wherein:

axial spacing of the first lens optic with respect to the second lens optic, when positioned within an evacuated capsular bag of a human eye, is such that the ciliary muscle of the wearer is operable to effect a visual accommodation of four diopters.

23. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens, said intraocular lens system comprising:

an anterior lens optic;

a posterior lens optic;

a first haptic means connected to and between said anterior lens and said posterior lens for partially supporting said lenses within the capsular bag and permitting relative axial motion of said anterior

lens with respect to said posterior lens while maintaining said posterior lens in an essentially stationary position; and

at least a second haptic means connected to and between said anterior lens and said posterior lens for partially supporting said lenses within the capsular bag and permitting relative axial motion of said anterior lens with respect to said posterior lens while maintaining said posterior lens in an essentially stationary position to provide accommodative bifocal vision to a patient.

24. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye, as defined in claim 23 wherein said at least a second haptic means comprises:

a second and a third haptic means connected to and between said anterior lens and said posterior lens.

25. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye, as defined in claim 24 wherein:

said first , second, and third haptic means are shaped in the form f a partial ellipse in longitudinal cross-section and the ratio f the ellipse is approximately 0.96.

26. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye, as defined in claim 25 wherein:

the transverse cross-sectional configuration of each of said first, second and third haptic means is substantially a circular arc and having a radius of curvature of approximately 4.5 mm.

27. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye, as defined in claim 26 wherein:

said first, second and third haptic means, when viewed along the line of sight of the anterior lens, extends outwardly at an angle of

approximately 40 degrees and the spacing between said first, second and third haptic means being approximately 80 degrees.

28. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens, said intraocular lens system comprising:

an anterior refractive lens optic;

a first haptic segment having a first end and being connected at said first end to a peripheral portion of said anterior lens optic and a second end and said haptic segment extending in an elliptical curve, in longitudinal cross-section; and

at least a second haptic segment having a first end and being connected at said first end to a peripheral portion of said lens optic and a second end and said at least a second haptic segment extending in an elliptical curve, in longitudinal cross-section, and being operably joined with the second end of said first haptic segment to form an open chamber, elliptical shaped haptic accommodating

support for the anterior lens within an evacuated capsular bag of a human eye.

29. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 28 wherein:

said anterior refractive lens is concave-convex in cross-section.

30. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 28 wherein:

said anterior refractive lens is plano-convex in cross-section.

31. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following

extracapsular extraction of a natural crystalline lens as defined in claim 28 wherein:

said anterior refractive lens is convex-plano in cross-section.

32. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 28 wherein:

the second ends of said haptics are each joined to a retaining ring at the posterior position of the intraocular lens system and said retaining ring abuts against the posterior surface of the capsular bag upon insertion of the intraocular lens within a human eye.

33. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 28 wherein:

the second ends f said haptics are each free and extend to a posterior position of the intraocular lens system and abut against the posterior surface of the capsular bag upon insertion of the intraocular lens within a human eye

34. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 32 wherein:

said at least a second haptic segment comprises a second and a third elliptical haptic segment spaced about the periphery of said anterior lens optic.

35. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 34 wherein:

said first , second, and third haptic segments are shaped in the form of a partial ellipse in longitudinal cross-section and the ratio of the ellipse is approximately 0.96.

36. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 35 wherein:

the transverse cross-sectional configuration of each of said first, second and third haptic segments is substantially a circular arc and having a radius of curvature of approximately 4.5 mm.

37. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 36 wherein:

said first, second and third haptic segments, when viewed along the line of sight of the anterior lens, extends outwardly at an angle of

approximately 30 to 40 degrees and said haptic segments being spaced equally about between said lenses.

38. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens said intraocular lens system comprising:

an anterior lens optic;

a posterior lens optic;

an intermediate lens optic positioned between and in visual axial alignment with said anterior and posterior lens optics;

a first haptic means connected to said anterior lens optic, said posterior lens optic and said intermediate lens optic and being operable for supporting said lenses within the capsular bag and permitting relative accommodative motion of said anterior lens with respect to said posterior lens; and

at least a second haptic means c nnected to said anterior lens optic, said posterior lens optic and said intermediate lens optic and being operable for cooperating with said first haptic means for supporting said lenses within the capsular bag and permitting relative accommodative motion of said anterior lens with respect to said posterior lens.

39. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 38 wherein:

said first haptic means comprises an elliptical haptic segment; and

said at least a second haptic means comprises a second and a third elliptical haptic segments, said first, second and third haptic segments being spaced about the periphery of said anterior and posterior lens optics.

40. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following

extracapsular extraction of a natural crystalline lens as defined in claim 39 wherein:

said first, second and third haptic segments, when viewed along the line of sight of the anterior lens, extends outwardly at an angle of approximately 40 degrees and the spacing between said first, second and third haptic segments being approximately 80 degrees.

41. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following extracapsular extraction of a natural crystalline lens as defined in claim 40 wherein:

said first , second, and third haptic segments are shaped in the form of a partial ellipse in longitudinal cross-section and the ratio of the ellipse is approximately 0.96.

42. An open chamber, accommodative, intraocular lens system operable to be positioned within an evacuated capsular bag of a human eye following

extracapsular extraction of a natural crystalline lens as defined in claim 41 wherein:

the transverse cross-sectional configuration of each of said first, second and third haptic segments is substantially a circular arc and having a radius of curvature of approximately 4.5 mm.

43. A method for achieving accommodative bifocal vision following an extracapsular operative procedure for removing a patient's natural crystalline lens, said method comprising the steps of:

inserting into the evacuated capsular bag an accommodative intraocular lens system including at least one lens optic and a plurality of elliptical and flexible haptic members forming an open chamber lens system having an exterior configuration approximating the shape of the interior surfaces of the evacuated capsular bag;

providing for near vision acuity by the natural memory state of the haptics of the intraocular lens system; and

providing accommodative far vision acuity by tensioning the zonual connected to the equator periphery of the evacuated capsular bag and thereby flattening the intraocular lens system haptic members and moving the lens in a posterior direction within the eye of a wearer of the accommodative intraocular lens system.

44. The method for achieving accommodative bifocal vision following an extracapsular operative procedure for removing a patient's natural crystalline lens as defined in claim 43, wherein:

said method being operable for refractive correction of a patient's myopia.

45. A method for achieving accommodative bifocal vision following an extracapsular operative procedure for removing a patient's natural crystalline lens as defined in claim 43 wherein:

said step of inserting includes inserting a first and a second lens optic into the evacuated capsular bag in an anterior position and a posterior position respectively; and

providing accommodative far vision comprises moving the anterior lens optic along an axis of sight toward the posterior lens within the interior of the evacuated capsular bag.

46. A method for achieving accommodative bifocal vision following an extracapsular operative procedure for removing a patient's natural crystalline lens as defined in claim 45 wherein:

said method being operable for restoring a patient's bifocal vision following cataract extraction.

47. A method for achieving accommodative bifocal vision following an extracapsular operative procedure for removing a patient's natural crystalline lens as defined in claim 45 wherein:

said method being operable for restoring a patient's bifocal vision to correct for presbyopia.

48. A method for achieving accommodative bifocal vision following an extracapsular operative procedure for removing a patient's natural crystalline lens as defined in claim 45 wherein:

said step of inserting further includes inserting a third lens optic into the evacuated capsular bag in a position between said first and second lens optics; and

said method being operable for providing a range of powers of 30 to 70 diopters for facilitating a patient's vision impaired by macular degeneration.

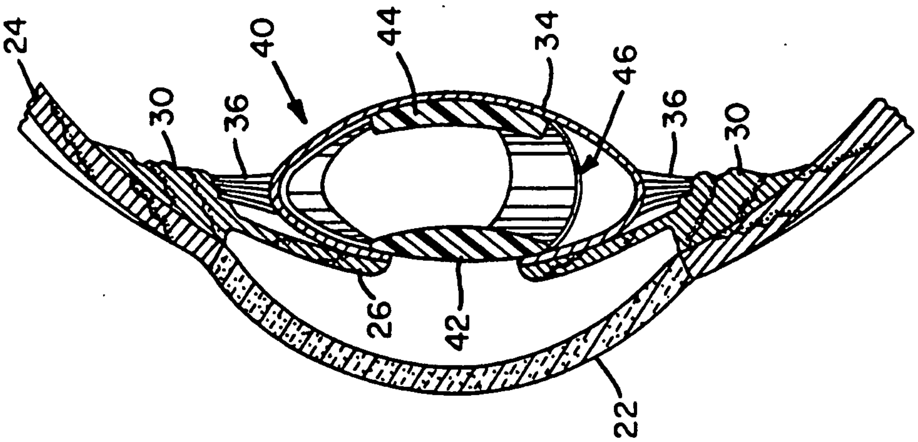

FIG. 2

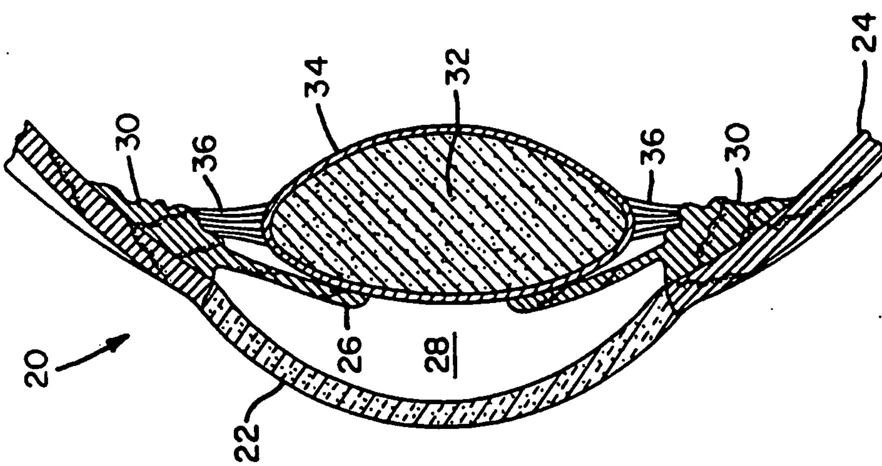

FIG. 1

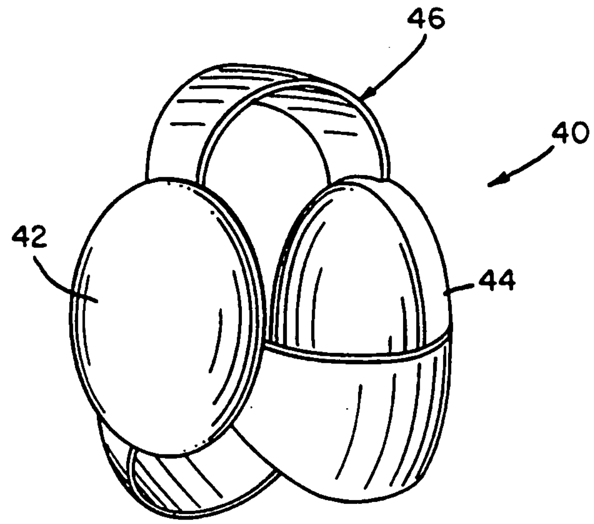

FIG. 3

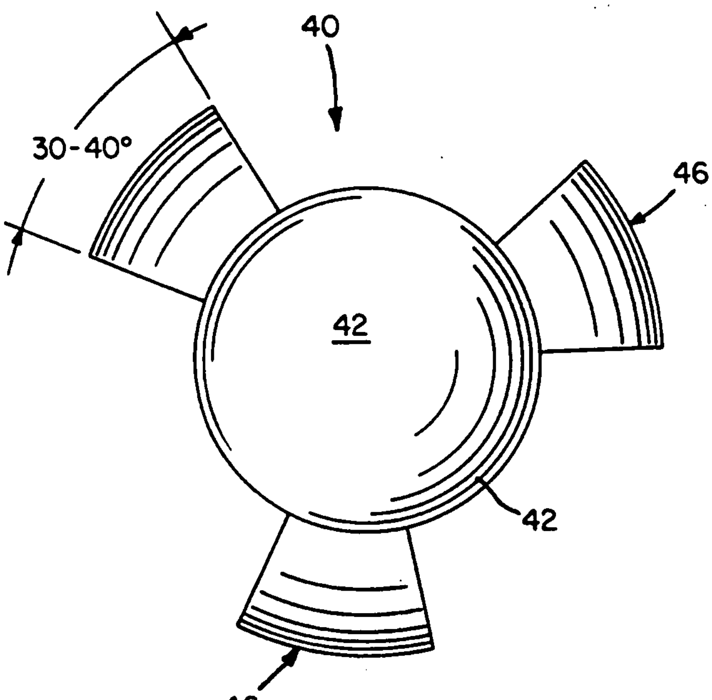

FIG. 4

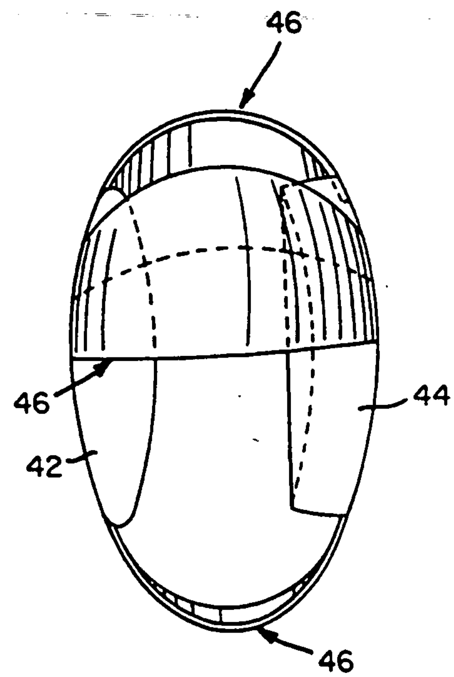

FIG. 5

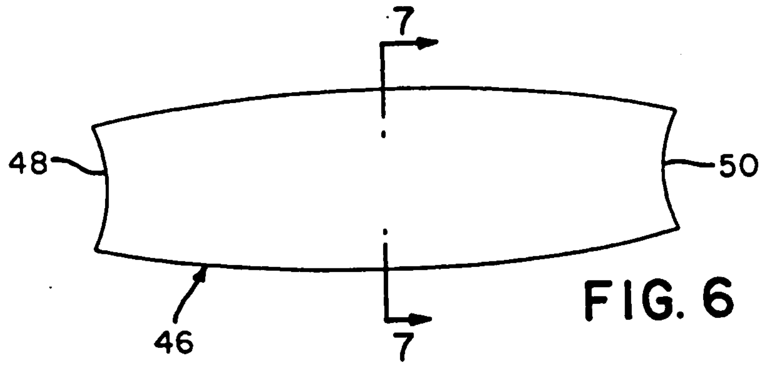

FIG. 6

FIG. 7

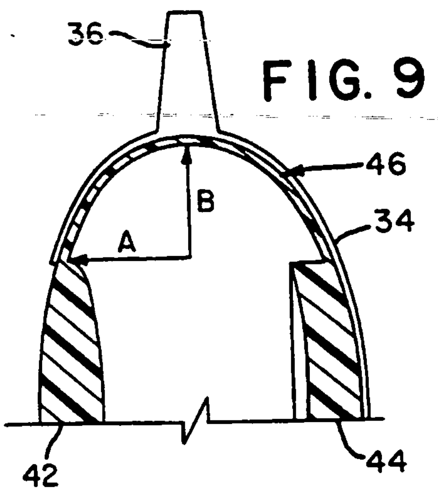

FIG. 9

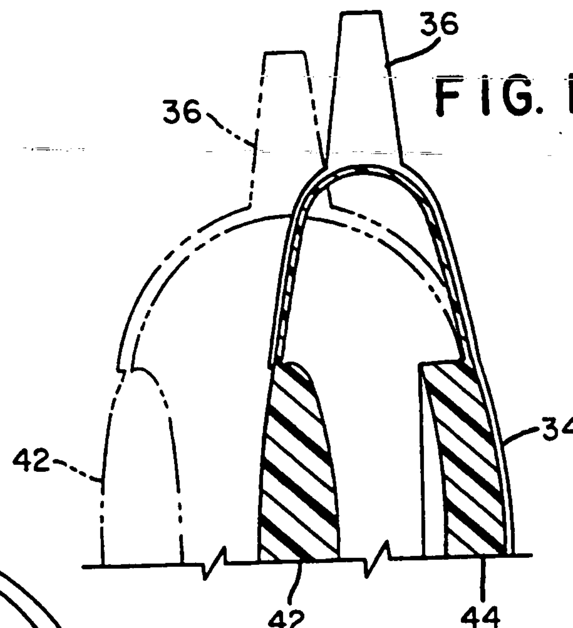

FIG. 10

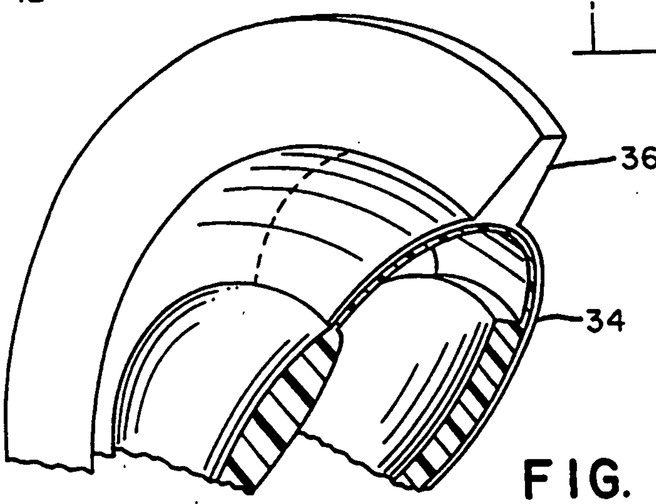

FIG. 8

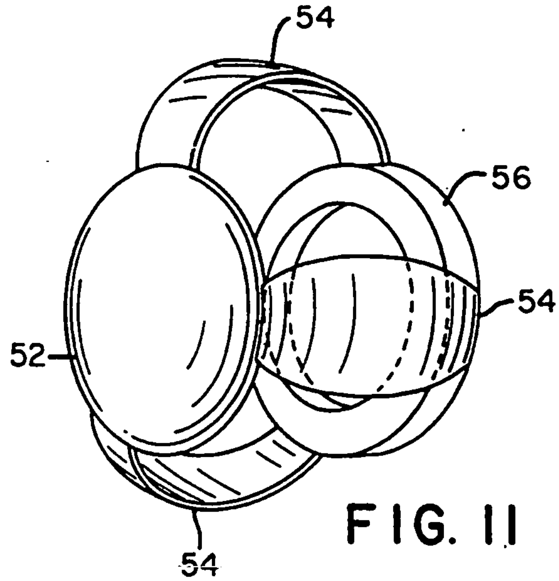

FIG. 11

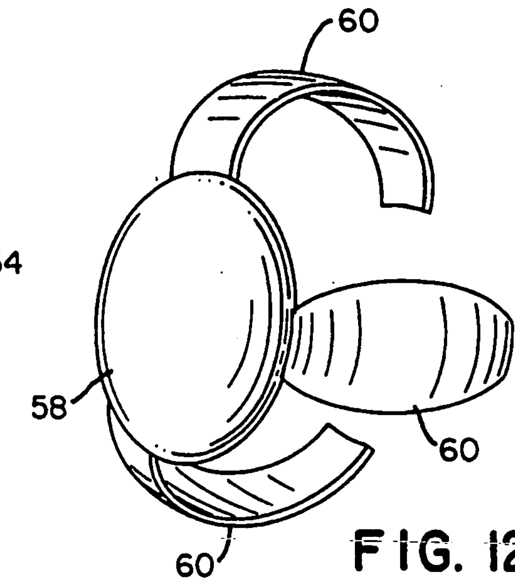

FIG. 12

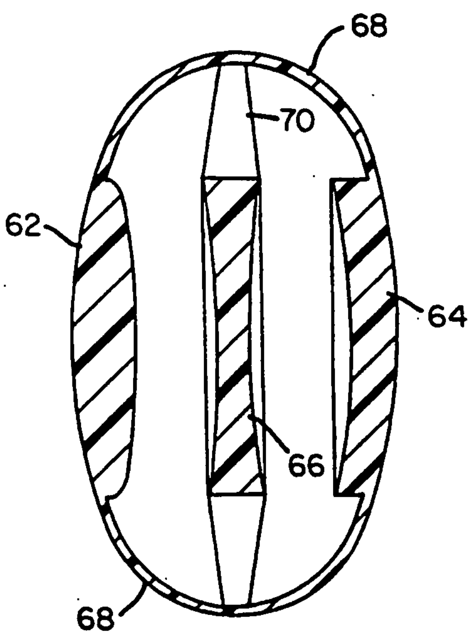

FIG. 14

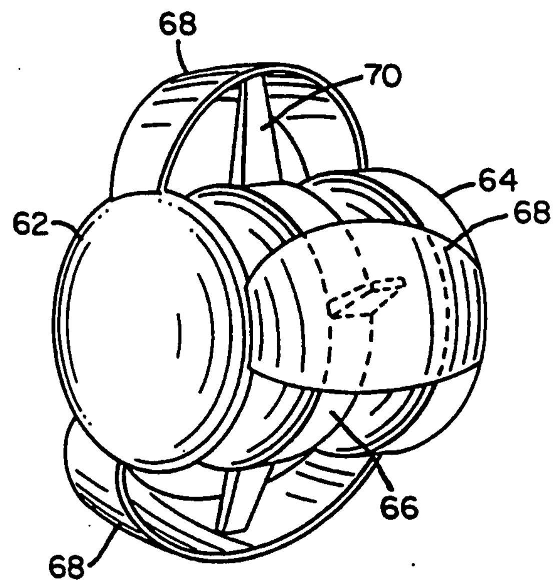

FIG. 13